DOCUMENT RESUME

ED 097 231 SE 018 460

AUTHOR Gray, T. Harrison; And Others
TITLE Speed and Accuracy of Addition in Normal Time and Decimal Time Systems.
INSTITUTION George Washington Univ., Alexandria, Va. Human Resources Research Office.
SPONS AGENCY Office of the Chief of Research and Development (Army), Washington, D.C.
REPORT NO HumRRO-TR-66-17
PUB DATE Oct 66
NOTE 37p.

EDRS PRICE MF-$0.75 HC-$1.85 PLUS POSTAGE
DESCRIPTORS *Addition; *Mathematics Education; *Measurement; Number Systems; *Research; *Time

ABSTRACT

This study compared the efficiency of decimal and sexagesimal, or normal, time systems in the solution of addition problems, using the time required to reach a solution and the number of errors as dependent variables. Twelve adult subjects solved sets of addition problems composed of 8, 16, or 24 digits, using the decimal and sexagesimal time systems. When the conversion process required by the sexagesimal system was included in the analysis, the results clearly showed that addition using the sexagesimal system required significantly more time (1 1/2 to 2 1/2 times as much) and produced significantly more errors (1 1/2 to 3 times as many). When the conversion process required by the sexagesimal system was excluded from the analysis, there was not significant difference between the two time systems on either dependent variable. (Author/DT)

Technical Report 66-17

Speed and Accuracy of Addition in Normal Time and Decimal Time Systems

by

T. Harrison Gray, T. Gary Waller and Robert H. Wright

HumRRO Division No. 6 (Aviation)

AD_____

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October 1966

Prepared for:

Office, Chief of Research and Development Department of the Army

Contract DA 44-188-ARO-2

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Technical Report 66-17
Work Unit LOWENTRY
Sub-Unit I!

The Human Resources Research Office is a nongovernmental agency of The George Washington University, operating under contract with the Department of the Army (DA 44-188-ARO-2). HumRRO's mission is to conduct research in the fields of training, motivation, and leadership.

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

Published
October 1966
by
The George Washington University
HUMAN RESOURCES RESEARCH OFFICE
300 North Washington Street
Alexandria, Virginia 22314

Distributed under the authority of the
Chief of Research and Development
Department of the Army
Washington, D.C. 20310

FOREWORD

Work Unit LOWENTRY has as its overall objectives the improvement of navigation techniques for low level flight in Army aircraft and the development of training methods to teach these techniques to aviation personnel. Activities directed toward these objectives were begun by the Human Resources Research Office in 1961 at Fort Rucker.

In Sub-Unit I, An Analysis of the Training Requirements for Low Altitude Navigation, factors influencing low level navigation have been defined, promising approaches explored, and development of training begun. In Sub-Unit II, an experimental source text on Army aircraft navigation is being prepared.

As one of several studies conducted to determine the feasibility of simplifying certain navigation techniques, the work reported here was performed to compare the efficiency of decimal and sexagesimal time systems. Other reports concerned with the problem of navigation techniques include Technical Report 65-8, *The Effect of Training on Accuracy of Angle Estimation*, by T. Gary Waller and Robert H. Wright, August 1965; Technical Report 65-9, *The Effects of Map Scale on Position Location*, by Ed Moon Edmonds and Robert H. Wright, September 1965; and a Consulting Report, *Pictorial Navigation Displays and Low Altitude Navigation*, by Robert H. Wright and Thomas G. Waller, April 1964. Reports in preparation include one dealing with direction estimation using tactical maps, and a general survey report of factors influencing Army low level navigation.

Research is conducted by the Human Resources Research Office under Army Contract DA 44-188-ARO-2 and Army Project 2JO24701A712-01, Training, Motivation, and Leadership Research. Work Unit LOWENTRY, Methods for Improving Navigation Training for Low Level Flight, is being performed at HumRRO Division No. 6 (Aviation), Fort Rucker, Alabama. Dr. Robert H. Wright was the Work Unit Leader for the research covered by this report. The present Director of Research of the Division is Dr. Wallace W. Prophet; Dr. J. Daniel Lyons was Director of Research at the time the research was begun.

Military support for the study was provided by the U. S. Army Aviation Human Research Unit. Work Unit LOWENTRY was begun when LTC Arne H. Eliasson was Unit Chief and continued while MAJ Donald J. Haid was Chief. LTC Berkeley D. More is the present Unit Chief.

Meredith P. Crawford
Director
Human Resources Research Office

SUMMARY AND CONCLUSIONS

PROBLEM

Low level navigation requires many computations which are time consuming and permit many possibilities for error. As presently accomplished, these computational procedures involve using the standard sexagesimal, or normal, time system (wherein 60 seconds equal one minute and 60 minutes equal one hour). A decimal time system (wherein time is measured by dividing the hour into decimal units of tenths, hundredths, etc.) uses a more familiar numerical system that would eliminate the necessity of converting seconds to minutes and minutes to hours, and might thereby improve speed and accuracy in the computational tasks. Following such a rationale, the present study investigated addition processes in decimal and sexagesimal (normal) time systems in order to discover the relative error probabilities and computational times for the two systems.

RESEARCH PROCEDURE

Twelve males served as subjects in the study. The subject's task was to add two, four, or six rows of four-digit numbers expressed in both decimal and sexagesimal time systems. The two dependent variables measured in the study were response time recorded in tenths of a second, and correctness of problem solution.

RESULTS

Using problems with similar digit distribution, when the conversion step required by the sexagesimal time system was included in the analysis, the results showed that time required for problem solution in the sexagesimal system was approximately 1½ to 2½ times that for the decimal system, and errors in the sexagesimal system occurred with a frequency approximately 1½ to 3 times that of the decimal system. These differences were statistically significant. When the conversion step required by the sexagesimal time system was omitted from the analysis, there were no significant differences between the two systems. When the sexagesimal time system was compared with the decimal time system composed of randomly selected digits, time for problem solution in the sexagesimal system was approximately 1¼ to 2 times that for the decimal system, and errors occurred with a frequency approximately 1¼ to 2 times that of the decimal system.

CONCLUSIONS

Based on the results of the study it may be concluded that performance in addition using the decimal time system is superior to performance in addition using the sexagesimal time system. The necessity for converting seconds to minutes and minutes to hours in the

sexagesimal system accounts for these differences. Adoption of a decimal system for measuring time should result in faster and more correct solutions for aerial navigation problems and contribute to simplification of the pilot's overall navigation task.

CONTENTS

	Page
INTRODUCTION	3
Statement of the Problem	3
Objective	3
Rationale	4
METHODS AND PROCEDURES	4
Subjects	4
Independent Variables	5
Design	5
Test Items	5
Dependent Variables	6
Apparatus	6
Testing Procedure	6
Scoring	6
RESULTS	7
Analysis of Response Time	7
Analysis of Errors	10
Column Differences	13
Correlational Findings	14
DISCUSSION AND INTERPRETATION	14
Comparison of Time Systems	14
Military Implications	14
APPENDICES	16
A Photograph of Testing Environment	16
B Instructions and Timing Procedure	17
C Mean Addition Time Per Digit (In Seconds)	19
D Analysis of Variance Source Tables for Time Scores	20
E Mean Errors Per Digit	22
F Analysis of Variance Source Tables for Error Scores	23
G Comparisons of Mean Addition Times and Mean Errors for Columns	25

TABLES

		Page
1	Mean Addition Time Per Problem in Seconds	7
2	Mean Number of Errors Per Problem	11
D-1	Decimal vs. Sexagesimal (Conversion Time Included).	20
D-2	Decimal vs. Sexagesimal (Conversion Time Excluded).	20
D-3	Numbers Within Decimal System Restricted to Digits 0, 1, 2, 3, 4, and 5 vs. Digits 6, 7, 8, and 9	21
F-1	Decimal vs. Sexagesimal (Conversion Errors Included).	23
F-2	Decimal vs. Sexagesimal (Conversion Errors Excluded).	23
F-3	Decimal Restricted High vs. Decimal Restricted Low	24

FIGURES

1	Comparison Between Decimal and Sexagesimal Time Systems with Conversion Time for Sexagesimal System Included	8
2	Comparison Between Decimal and Sexagesimal Time Systems with Conversion Time for Sexagesimal System Excluded.	9
3	Comparison Between Decimal Restricted High and Decimal Restricted Low Problems	10
4	Error Comparison Between Decimal and Sexagesimal Time Systems with Conversion Errors Included	12
5	Error Comparison Between Decimal and Sexagesimal Time Systems with Conversion Errors Excluded	12
6	Error Comparison Between Decimal Restricted Low Problems	13

Speed and Accuracy of Addition in Normal Time and Decimal Time Systems

INTRODUCTION

STATEMENT OF THE PROBLEM

Successful navigation requires many computations. In practically all of these computations, except those involving time, the units of measurement are based on the decimal numerical system. In fact, most of the prior experience of the pilot (or navigator) in performing numerical computations has been restricted to a decimal numerical system. This restricted experience is a product not only of flight training but of everyday life as well.

Low level navigation requires that flight time be accurately determined and that it be expressed in hours, minutes, and seconds. As a complicating factor, it is also true that low level navigation may demand an indirect flight path in order that the pilot may maintain orientation by referring to salient geographic features. Since the navigational legs of an indirect flight path are usually of limited duration, successful low level navigation requires numerous additions of the minutes and seconds that occur in each navigational leg. The typical procedure is to add the total number of seconds, convert this result into minutes and seconds, carry the minutes to the minute column, add these figures and convert the total number of minutes into hours and minutes. This procedure can be time consuming and permits numerous possibilities for error.

Although certain logical advantages have been pointed out for a complete conversion of all time and angular measurement to a decimal basis,[1] the present study is oriented to a more restricted concept using an hour-decimal replacement for the present sexagesimal time system. The use of such a decimal time system might provide a superior basis for flight planning, because it avoids the conversion step inherent in the sexagesimal time system upon which present navigation methods are founded, and it employs a more familiar numerical base. Therefore, the present study investigated the relative efficiency of decimal and sexagesimal time systems as used in addition problems.

OBJECTIVE

The objective of this study was to compare the decimal and sexagesimal time systems in terms of (a) their relative error probabilities and (b) the time required to solve the problems.

---

[1]Schisler, Capt. Charles W. "Do It With Decimals," *The Navigator*, Vol. XII, No. 1, 1964, pp. 13-15.

RATIONALE

The present study was one of several Work Unit LOWENTRY studies intended to discover means for reducing the time required and the occurrence of errors in the performance of aerial navigation tasks. The approach followed was fundamentally that of task simplification through the introduction of new procedures or equipment. The rationale for the study assumed that errors in low level navigation are frequently not a result of the selection of improper procedures, but instead are often mechanical mistakes occurring in computations. Research by Trumbull[1] supported this assumption and indicated that these mistakes can occur at any time during flight.

One potential means for reducing time and error in navigation task performance would be to eliminate the use of the sexagesimal numerical system for measuring time. All other information used in navigational procedures is in the decimal numerical system; therefore, problem solution requires conversion of time to its decimal or fractional equivalent before it can be used in mental time-distance-speed computations. The pilot usually finds it difficult to "think" in terms of a combined sexagesimal-decimal problem; this means that time measures must be converted to their decimal equivalent for the pilot to use them in mental time-distance-speed computations. At normal altitudes this situation is of little concern because the flight computer can be used. But at low level it is usually impractical to use the flight computer, and determination of time-distance-speed relationships on a mental basis would therefore be highly desirable. It is considered likely that a decimal system for measurement of time would make such mental computations practical.

METHODS AND PROCEDURES

SUBJECTS

Twelve males from 22 to 45 years of age served as subjects in the study. The subjects' educational attainments ranged from high school graduation through the Ph.D. degree, and familiarity with low level navigation problems varied from that obtained through casual acquaintance with field manuals and technical publications to the actual solution of problems worked out while flying an aircraft.

---

[1]Trumbull, Lt. Richard. *Analysis of Basic Factors Constituting Necessary Mathematical Proficiency Required for Success in Naval Aviation: Report I. Addition*, Research Report No. NM 001 058.20.01, U. S. Naval School of Aviation Medicine, U. S. Naval Air Station, Pensacola, Florida, July 1952.

INDEPENDENT VARIABLES

Two independent variables in the addition process were used. The first was type of time system--decimal and sexagesimal. The second independent variable was problem length.

DESIGN

The study used a 12 x 3 x 2 factorial design with repeated measures of the performance of 12 subjects working addition problems of three lengths in two time systems. Problem length was varied by using either two, four, or six rows of four-digit numbers, resulting in problems with either 8, 16, or 24 digits. Twelve different problems were used for each problem length and time system combination, a procedure that resulted in 72 problems for each subject--36 in the decimal time system and 36 in the sexagesimal time system. In the 36 decimal problems the digits in the second and fourth columns from the right were restricted to the digits 5, 4, 3, 2, 1 and 0. This restriction was used to make the digits in these columns comparable to the digits occurring in the corresponding columns in the sexagesimal time system. No restrictions were placed on the digits in the first and third columns from the right.

For supplementary data, 12 additional decimal problems with different restrictions were included, 6 of four-row problem length, and 6 of six-row problem length. For these 12 supplementary problems the digits in the second and fourth columns from the right were restricted to the numbers 6, 7, 8, and 9. These problems were included in order to estimate the effect of the numerical restrictions involved in the sexagesimal numerical system and thereby to allow a comparison of an unrestricted decimal system with the sexagesimal system. Six of these supplementary problems were given at the end of the first 36 problems in the primary design, and the remaining 6 were administered at the conclusion of the test.

Although Sampsen[1] has reported that presentation order of problems does not play a significant role in the performance, in order to insure randomization, each of the 72 primary design problems was randomly presented to the subject, one at a time, on a separate slip of paper. With the exception as to placement noted above, the same procedure was used for the 12 supplementary problems.

TEST ITEMS

The test items were addition problems composed of four columns of randomly determined numbers, subject to the restrictions previously mentioned. For example,

.2431
.5745 illustrates a decimal time system

[1]Sampsen, H. "Serial Addition as a Function of Stimulus Duration and Pacing," *Canadian Journal of Psychology*, vol. 12, 1958, pp. 179-183.

problem of two rows with 8 digits, and

27 min 13 sec
19 min 50 sec
24 min 36 sec
37 min 43 sec

___hr___min___sec

illustrates a sexagesimal time system problem of four rows with 16 digits.

DEPENDENT VARIABLES

Two dependent variables were measured. The first of these was response time measured in tenths of a second. In all, three response time measures were recorded:

(1) Time to add the first two columns from the right.
(2) Time to add the second two columns from the right.
(3) Time required to convert minutes and seconds into hours, minutes and seconds. (Answers to all sexagesimal problems required conversion.)

The second dependent variable was correctness of solution. The subject's answers were graded for accuracy, and a simple right or wrong score recorded.

APPARATUS

The apparatus used to record response latency and the testing environment are shown in the photograph in Appendix A. Essentially, the timing device consisted of three stopwatches arranged so that any two could be simultaneously stopped or started as required by the problem phases.

TESTING PROCEDURE

Standard testing procedures were used for all subjects. The subject was brought in, seated at a work table, and the instructions given in Appendix B were read to him. The examiner answered any questions concerning the task and proceeded with the testing.

SCORING

The subject's score for each problem consisted of two parts. The first score was the amount of time required to solve the various phases of the problems. The second score was the correctness of addition for the subparts and for the final answer.

The time scores for each problem phase were recorded by the examiner after the subject completed the problem.

RESULTS

ANALYSIS OF RESPONSE TIME

Table 1 lists the mean addition time per problem for each time system at each level of problem length. These data show that the mean addition time required by the sexagesimal time system (conversion time included) for two-row problems (12.2 seconds) was 139% greater than the mean addition time (5.1 seconds) required by the restricted decimal time system. For four-row problems the sexagesimal system required 66% more time, and for six-row problems the sexagesimal system required 48% more time. When the conversion time for the sexagesimal time system was excluded, the mean addition times required by the sexagesimal and restricted decimal systems were approximately equal. Within the decimal time system, for four-row problems, when the mean addition time required by the problems restricted to the low digits (5, 4, 3, 2, 1, and 0) in the second and fourth columns from the right was compared with the mean addition time required by the problems restricted to the high digits (9, 8, 7, and 6) in these columns, it was found that the latter class of problems required 46% more time. Similarly, six-row problems required 46% more time. Finally, when the mean addition time required by the sexagesimal time system (conversion time included) was compared with the mean addition time required by random digits in the decimal system, two-row problems required 94% longer in the sexagesimal system; four-row problems, 40% longer; and six-row problems, 25% longer. Table 1 also shows that mean conversion times (6.6, 9.5, and 13.7 seconds) show an approximately linear relationship which is dependent upon problem length. Additional information is found in Appendix C which gives the mean time, in seconds, for the addition of certain digits.

Table 1

MEAN ADDITION TIME PER PROBLEM IN SECONDS

Problem Length	Sexagesimal System			Decimal System		
	Add	Convert	Total	Low[a]	High[b]	Random[c]
Two Rows (8 digits)	5.6	6.6	12.2	5.1	---	6.3
Four Rows (16 digits)	15.2	9.5	24.7	14.9	21.7	17.6
Six Rows (24 digits)	23.8	13.7	37.6	25.5	37.2	30.2

[a] *Second and fourth columns from right restricted to digits 0, 1, 2, 3, 4, and 5.*

[b] *Second and fourth columns from right restricted to digits 6, 7, 8, and 9.*

[c] *Estimate from trends and algebraic derivation.*

In order to determine if the addition time differences reported above were significant, three analyses of variance were performed. The source tables for these analyses are given in Appendix D. In these and other analyses in this report the .05 level ($p<.05$) was used in determining statistical significance.

When the main effects for the restricted decimal time system were compared with the main effects for the sexagesimal time system (including the conversion time required by the sexagesimal time system) the results were clear-cut. The mean time per problem in the decimal system for all three problem lengths was significantly less ($p<.001$) than the corresponding mean time per problem in the sexagesimal system. Figure 1 illustrates the mean addition times for the three problem lengths and the two time systems.

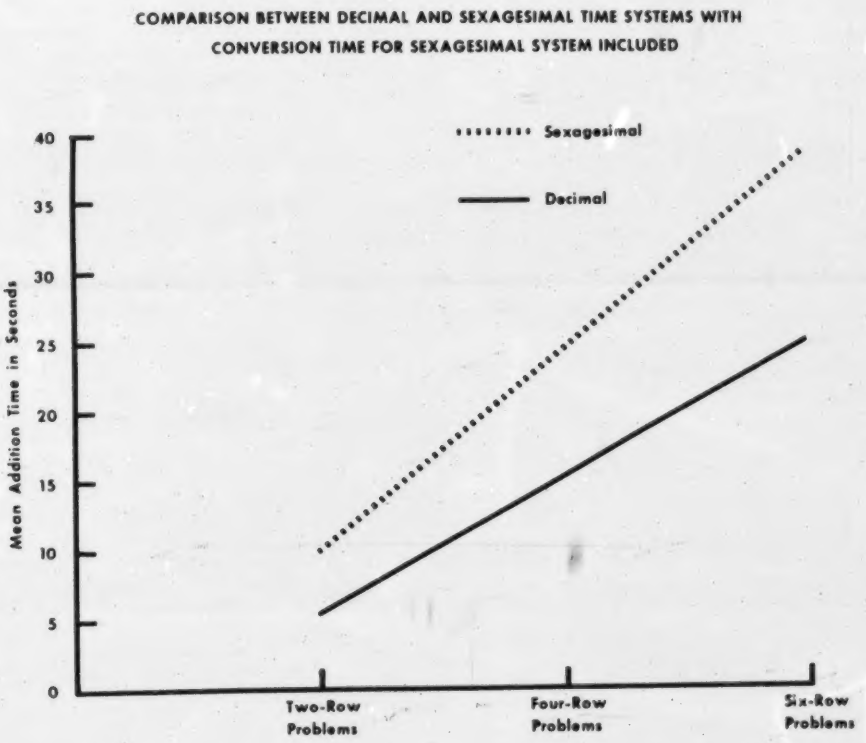

Figure 1

When the addition time required by the restricted decimal time system was compared with the addition time required by the sexagesimal time system (excluding the sexagesimal conversion time), a different result was found. Aside from interactions, this analysis indicated no significant difference between the decimal and sexagesimal systems for all problem lengths. Figure 2 illustrates these mean values.

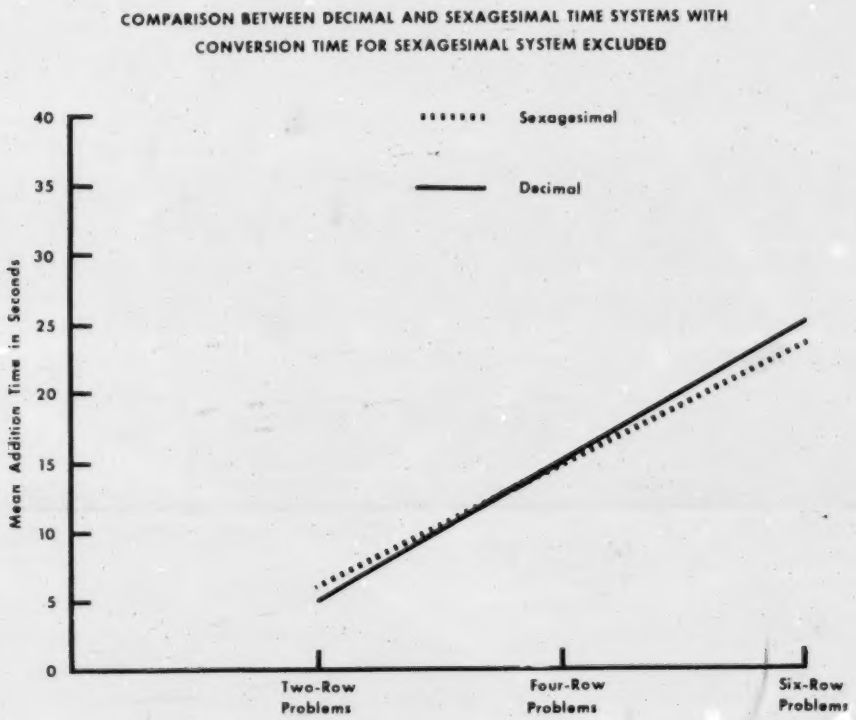

Figure 2

Finally, when the addition response time analysis was based on the complexity of the addition operations, within the decimal time system itself, there was a significant difference ($p<.01$) between the times required to solve the high and low digit problems (interactions not considered). Figure 3 illustrates this finding.

As a general rule, and as would be expected, there were significant differences associated with the length of the problems--the longer the problem, the longer it took to work it.

All three analyses of variance showed a significant ($p<.01$) interaction existing between number of rows and time systems. This reflects the fact that the differences in mean time for problem solution between the two systems became progressively greater as problem complexity increased.

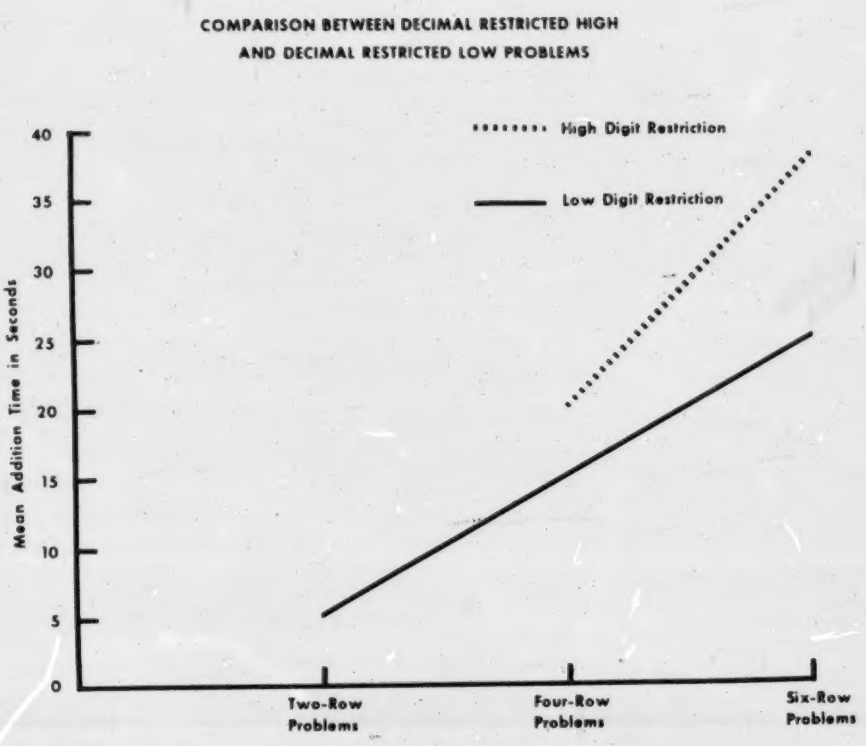

Figure 3

ANALYSIS OF ERRORS

Table 2 lists the mean number of errors per problem for each time system at each level of problem length. These data show that in the sexagesimal time system (conversion errors included) for two-row problems the mean number of errors per problem (0.09) was 200% greater than the mean number of errors per problem (0.03) in the restricted decimal time system. For four-row problems there were 144% more errors per problem in the sexagesimal system, and for six-row problems there were 59% more errors. When the sexagesimal time system conversion errors were excluded, the mean number of errors in the sexagesimal and restricted decimal systems were approximately equal. Within the decimal time system, the mean number of errors for the problems restricted to the high digits (9, 8, 7, and 6) in the second and fourth columns from the right were 89% greater than the number of errors for the four-row problems restricted to the low digits (5, 4, 3, 2, 1, and 0) in similar columns; and for six-row problems, 65% greater. Finally, when the mean number of errors in the sexagesimal time system (conversion errors included) were

compared with the mean number of errors produced by random digits in the decimal system, two-row problems in the sexagesimal system produced 80% more errors; four-row problems produced 83% more errors; and six-row problems produced 29% more errors. Additional information is found in Appendix E which gives the mean number of errors for the addition of certain digits.

Table 2

MEAN NUMBER OF ERRORS PER PROBLEM

Problem Length	Sexagesimal System			Decimal System		
	Add	Convert	Total	Low[a]	High[b]	Random[c]
Two Rows (8 digits)	0.03	0.06	0.09	0.03	---	0.05
Four Rows (16 digits)	0.14	0.08	0.22	0.09	0.17	0.12
Six Rows (24 digits)	0.15	0.12	0.27	0.17	0.28	0.21

[a]*Second and fourth columns from right restricted to digits 0, 1, 2, 3, 4, and 5.*

[b]*Second and fourth columns from right restricted to digits 6, 7, 8, and 9.*

[c]*Estimate from trends and algebraic derivation.*

In order to determine if the mean error differences reported above were significant, three analyses of variance were performed. The source tables for these analyses are given in Appendix F.

When the errors occurring in the restricted decimal time system were compared with the errors (including conversion errors) in the sexagesimal time system, the analysis showed that significantly fewer errors ($p<.01$) were made in the decimal system. These means are illustrated by Figure 4.

Of the total number of errors produced by the sexagesimal problems, approximately 45% were made in the conversion step. When the remaining errors made in the addition process of the sexagesimal problems were compared with the errors made in the restricted decimal system, no significant difference was found between the two systems. Figure 5 illustrates this result.

As would be expected, a significant difference ($p<.01$) did exist among problem lengths, with greater lengths producing significantly more errors.

Finally, when the error analysis was based on the complexity of the addition operation, solely within the decimal time system by using mean errors in the restricted high and the restricted low problems, there was a significant difference ($p<.01$) between the number of errors produced and the complexity of the problem. Figure 6 illustrates these data.

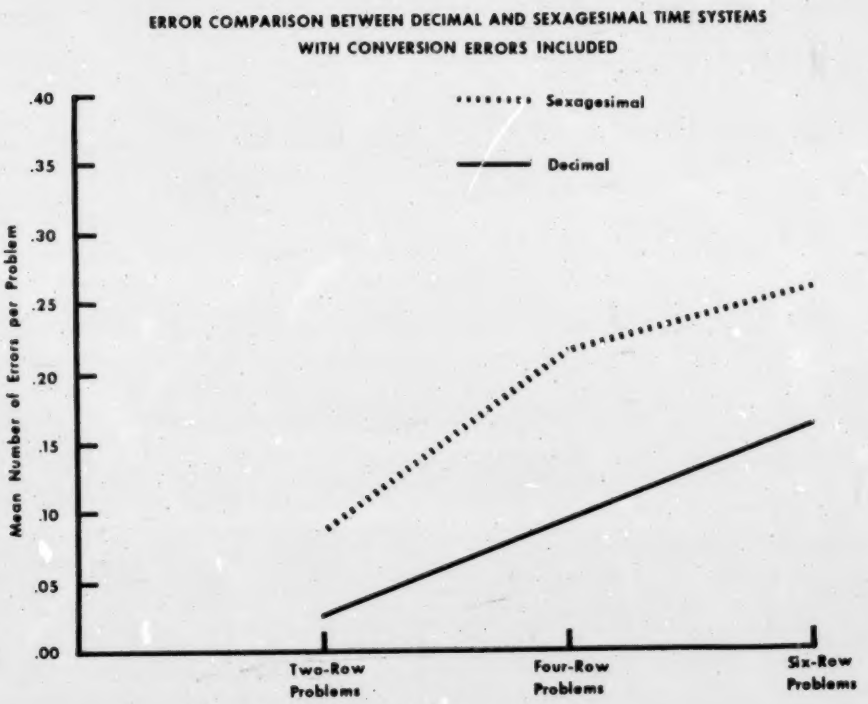

Figure 4

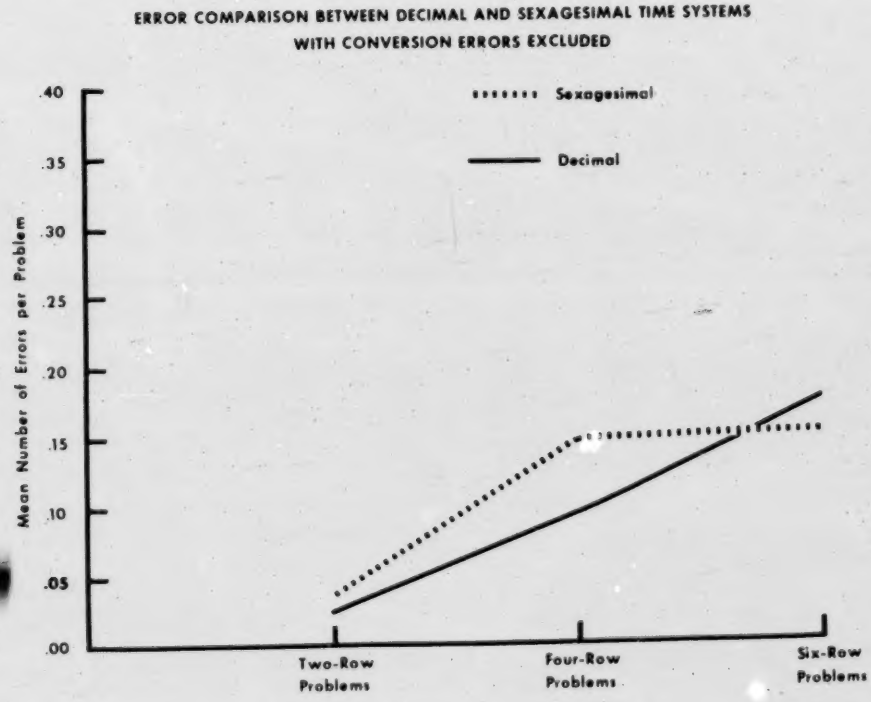

Figure 5

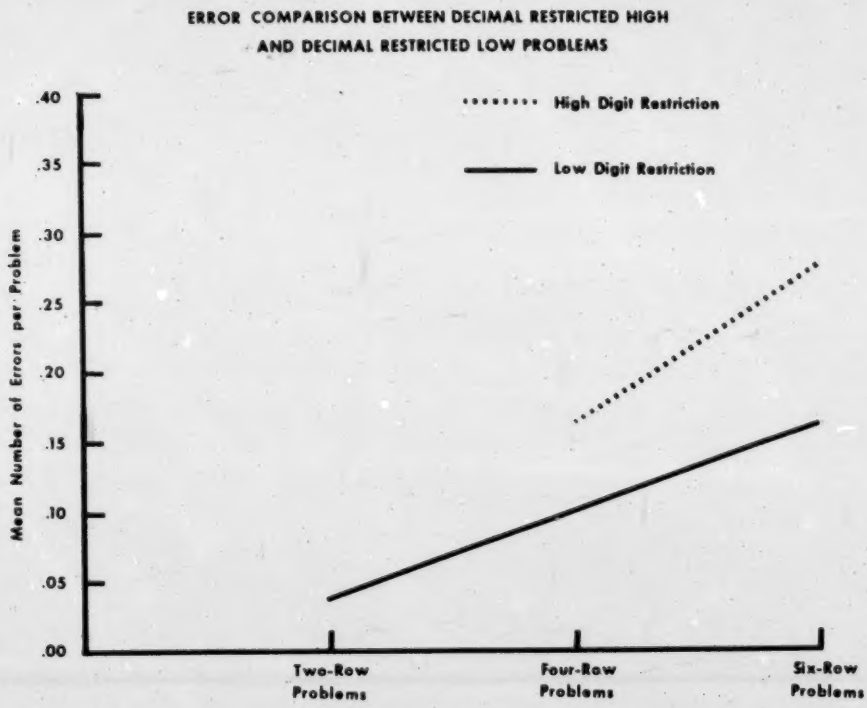

Figure 6

These results satisfactorily paralleled the findings using addition time as the dependent variable. For both time per problem and total errors, performance using the sexagesimal time system was inferior to that using the decimal time system, because of the conversion step involved.

For the three analyses of variance performed using the error scores as the dependent variable there were no significant interactions.

COLUMN DIFFERENCES

Since the sexagesimal problems were given in minutes and seconds, two columns of digits were added, the left-hand column pair being minutes and the right-hand pair being seconds. The differences in mean time and mean number of errors between the right and left column pairs are given in Appendix G.

CORRELATIONAL FINDINGS

Based on the performance of the 12 subjects, Pearson product-moment correlations were computed in order to determine the size and nature of the relationships between the dependent variables. The correlation between the total time required for solution of restricted decimal problems and the total time required for solution of sexagesimal problems was +.92 (df=10, p<.01). The correlation between the total time required for solution for restricted decimal problems and total number of problems correct was -.18 (df=10, *NS*). The correlation between the total time required for solution for sexagesimal problems and total number of problems correct was +.03 (df=10, *NS*).

DISCUSSION AND INTERPRETATION

COMPARISON OF TIME SYSTEMS

The results of the study showed the decimal time system to be superior to the sexagesimal time system when used to solve problems in addition. The superiority of the decimal system was shown both by decreased addition time and by fewer errors. The inferiority of the sexagesimal time system was accounted for by the extra step--conversion from minutes and seconds to hours, minutes, and seconds.

The above statements are the direct implications of the data. However, the nature of the restrictions placed upon the decimal problems used in this study require further interpretation. It will be recalled that in all but 12 of the decimal problems the digits in columns two and four from the right were restricted to the integers 0 through 5. The reason for this restriction was to make the digit constitution of the decimal problems comparable to that of the sexagesimal problems. It is obvious, of course, that in an operational environment such a restriction would not occur. In such an environment the digits would approach a random distribution.

A clearly definitive answer to the question of decimal versus sexagesimal time systems would require a study using unrestricted decimal and sexagesimal problems. Although this was not done in the present study, it is possible to use the data of the study to develop an answer that should be satisfactory for many applied purposes.

MILITARY IMPLICATIONS

The results of this study indicate that the adoption of a decimal time system for Army aviation should result in the addition aspect of air navigation problems being solved with greater accuracy and speed. The use of a decimal time system would also permit the design of a simpler flight computer based upon a single numerical system rather than the two systems presently required. It could be expected that

this simplification of computer design, along with the resultant reduction in the number of procedural routines required for the solution of navigation problems, should result in improved speed and accuracy in the use of the flight computer.

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Appendix A

PHOTOGRAPH OF TESTING ENVIRONMENT AND TIMER

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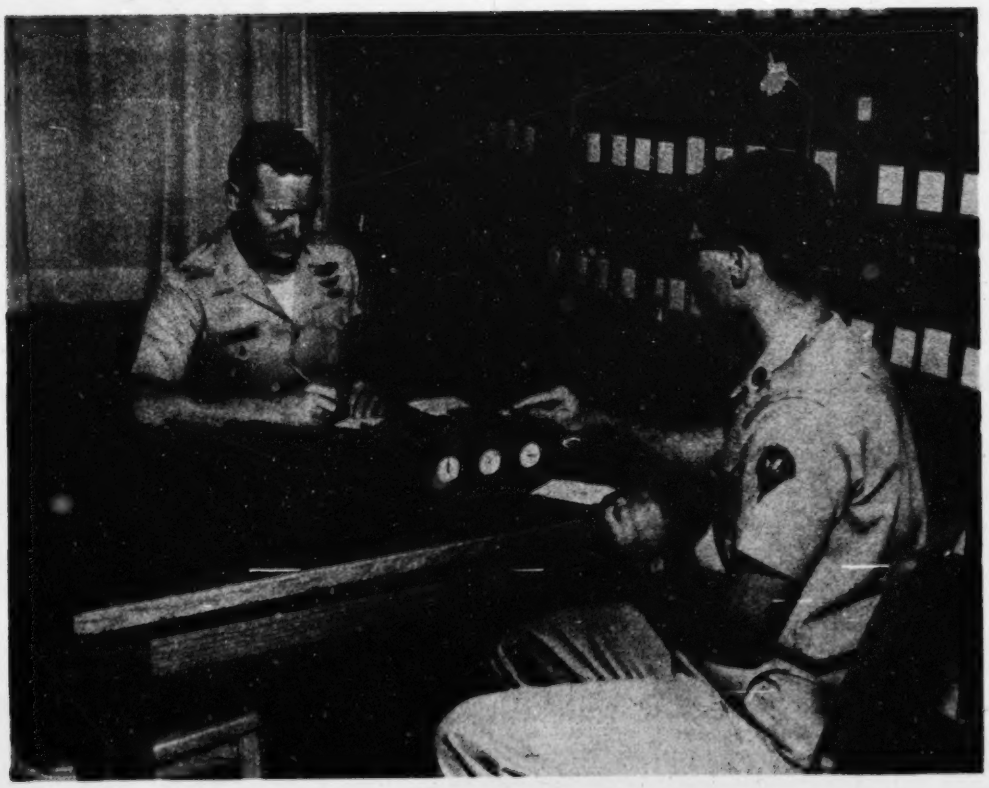

Appendix B

INSTRUCTIONS AND TIMING PROCEDURE

Instructions

You are to work a series of short addition problems. On some of the problems, you will add numbers which are four-digit decimals. For example:

$$\begin{array}{r} .1234 \\ .9876 \\ \hline 1.1110 \end{array}$$

On the other problems, you will add "time" as given in minutes and seconds. For example:

$$\begin{array}{r} 24 \text{ min } 36 \text{ sec} \\ 48 \text{ min } 27 \text{ sec} \\ \hline 72 \text{ min } 63 \text{ sec} \end{array}$$

$$1 \text{ hr } 13 \text{ min } 03 \text{ sec}$$

The answers to all the "time" problems must be converted to seconds, minutes, and hours, as shown in the example. You must complete the addition part of the problem before you convert the answer to seconds, minutes, and hours. When you do the conversion, work from right to left; i.e., convert to seconds, minutes, and hours, in that order.

I will time you on each problem. In front of you is a stack of small sheets of paper. When I say "go," you are to turn over the first sheet and immediately begin to work the problem. When you complete the problem, hand the sheet of paper to me. Do not begin the next problem until I say "go."

Work as accurately and quickly as possible. Be careful, but do not waste time. Remember to convert the answers on the "time" problems.

Do you have any questions? (Pause) If not, you may start on the six sample problems. Do not begin until I say "go."

Timing Procedure

1. Stop Watch #1 was started after the subject had turned over the problem sheet and started to work on the problem.

2. When the subject finished writing the second digit, Stop Watch #1 was stopped and Stop Watch #2 was started.

3. When the subject finished writing the first (lead off) digit of the 4th column, Stop Watch #2 was stopped and Stop Watch #3 was started.

4. When the subject finished writing the second (lead off) digit of the minutes section, Stop Watch #3 was stopped.

5. The times were recorded by the experimenter and the subject was started on the next problem.

Appendix C

MEAN ADDITION TIME PER DIGIT (IN SECONDS)

Problem Length	Digits 0, 1, 2, 3, 4, 5	Random[a] Digits	Digits 6, 7, 8, 9
Two Rows (8 digits)	0.49	0.79	1.24
Four Rows (16 digits)	0.77	1.10	1.61
Six Rows (24 digits)	0.87	1.26	1.84

[a]*Interpolating from the observed data, in a set of randomly occurring digits, for a two-row addition problem the mean time per digit would be .79 seconds; for a four-row addition problem the mean time per digit would be 1.10 seconds; and for a six-row addition problem the mean time per digit would be 1.26 seconds.*

Appendix D

ANALYSIS OF VARIANCE SOURCE TABLES FOR TIME SCORES

Table D-1

Decimal vs. Sexagesimal (Conversion Time Included)

Source of Variation	*df*	*ss*	*MS*	*F*
Subjects	11	19,968,074	1,815,279	
Problem Length (Levels)	2	90,360,621	45,180,311	179.6***
Systems	1	24,137,352	24,137,352	196.0***
Subjects X Levels	22	5,535,280	251,604	
Subjects X Systems	11	1,354,918	123,174	
Levels X Systems	2	1,122,901	561,451	19.4***
Subjects X Levels X Systems	22	637,902	28,996	
Total	71	143,117,048		

****Significant at .001.*

Table D-2

Decimal vs. Sexagesimal (Conversion Time Excluded)

Source of Variation	*df*	*ss*	*MS*	*F*
Subjects	11	12,679,573	1,152,688	
Problem Length (Levels)	2	64,495,486	32,247,743	148.0***
Systems	1	24,827	24,827	1.9
Subjects X Levels	22	4,793,589	217,890	
Subjects X Systems	11	141,637	12,876	
Levels X Systems	2	229,369	114,685	4.9**
Subjects X Levels X Systems	22	427,259	19,421	
Total	71	82,791,740		

***Significant at .01.*
****Significant at .001.*

Table D-3

Numbers Within Decimal System Restricted
to Digits 0, 1, 2, 3, 4, and 5 vs. Digits 6, 7, 8, and 9

Source of Variation	*df*	*ss*	*MS*	*F*
Subjects	11	19,194,814	1,744,983	12.0**
Problem Length (Levels)	1	20,351,263	20,351,263	5.9*
Restricted High-Low	1	10,190,869	10,190,869	
Subjects X Levels	11	1,858,294	168,936	
Subjects X Restricted High-Low	11	1,891,272	171,934	
Levels X Restricted High-Low	1	747,052	747,052	23.9***
Subjects X Levels X Restricted High-Low	11	343,871	31,261	
Total	47	54,577,435		

*Significant at .05.
**Significant at .01.
***Significant at .001.

Appendix E

MEAN ERRORS PER DIGIT

Problem Length	Digits 0, 1, 2, 3, 4, 5	Random[a] Digits	Digits 6, 7, 8, 9
Two Rows (8 digits)	0.0020	0.0058	0.0115
Four Rows (16 digits)	0.0037	0.0075	0.0135
Six Rows (24 digits)	0.0051	0.0088	0.0144

[a]*Interpolating from the observed data, in a set of randomly occurring digits, for a two-row addition problem the mean error per digit would be 0.0058; for a four-row addition problem the mean error per digit would be 0.0075; and for a six-row addition problem the mean error per digit would be 0.0088.*

Appendix F

ANALYSIS OF VARIANCE SOURCE TABLES FOR ERROR SCORES

Table F-1

Decimal vs. Sexagesimal (Conversion Errors Included)

Source of Variation	*df*	*ss*	*MS*	*F*
Subjects	11	54.44	4.95	
Problem Length (Levels)	2	43.02	21.51	11.3***
Systems	1	24.50	24.50	14.8***
Subjects X Levels	22	41.98	1.91	
Subjects X Systems	11	18.17	1.65	
Levels X Systems	2	2.09	1.10	1.1
Subjects X Levels X Systems	22	22.24	1.01	
Total	71	206.44		

****Significant at .001.*

Table F-2

Decimal vs. Sexagesimal (Conversion Errors Excluded)

Source of Variation	*df*	*ss*	*MS*	*F*
Subjects	11	41.37		
Problem Length (Levels)	2	28.00	14.00	11.4***
Systems	1	.34	.34	<1
Subjects X Levels	22	27.00	1.23	
Subjects X Systems	11	12.16	1.05	
Levels X Systems	2	2.11	1.06	1.4
Subjects X Levels X Systems	22	16.89	.77	
Total	71	127.87		

****Significant at .001.*

Table F-3

Decimal Restricted High vs. Decimal Restricted Low

Source of Variation	*df*	*ss*	*MS*	*F*
Subjects	11	.51	.046	
Problem Length (Levels)	1	.10	.100	4.4
Restricted High-Low	1	.11	.110	11.0**
Subjects X Levels	11	.25	.023	
Subjects X Restricted High-Low	11	.11	.010	
Levels X Restricted High-Low	1	.00	.000	<1
Subjects X Levels X Restricted High-Low	11	.17	.015	
Total	47	1.25		

***Significant at .01.*

Appendix G

COMPARISONS OF MEAN ADDITION TIMES AND MEAN ERRORS FOR COLUMNS

The mean time per problem required to add the left pair of columns and the right pair of columns is listed in the following table. Analysis of these column means showed that no significant differences existed between them for both the restricted decimal and sexagesimal time systems for the two-row problems. For the four-row problems, the difference between the decimal column means would have occurred by chance less than 5% of the time, but the difference between the sexagesimal column means was not significant. For the six-row problems, for both the decimal and sexagesimal time system column means, differences existed that would have occurred by chance less than 1% of the time.

Mean Time in Seconds to Add
Left and Right Pairs of Columns

Problem Length	Sexagesimal System		Decimal System	
	Left Pair	Right Pair	Left Pair	Right Pair
Two Rows (8 digits)	2.80	2.75	2.56	2.56
Four Rows (16 digits)	7.81	7.41	7.91	7.03
Six Rows (24 digits)	12.71	11.12	13.63	11.84

The mean number of errors per problem produced by adding the left pair of columns and the right pair of columns is listed in the table below. Statistical analyses showed that no significant differences existed between the left and right pairs of column means for both the sexagesimal and decimal time systems.

Mean Errors Produced in Adding
Left and Right Pairs of Columns

Problem Length	Sexagesimal System		Decimal System	
	Left Pair	Right Pair	Left Pair	Right Pair
Two Rows (8 digits)	.0140	.0208	.0208	.0069
Four Rows (16 digits)	.0902	.0486	.0416	.0486
Six Rows (24 digits)	.0625	.0833	.0902	.0763

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Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*

Human Resources Research Office
The George Washington University
Alexandria, Virginia 22314

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

3. REPORT TITLE

SPEED AND ACCURACY OF ADDITION IN NORMAL TIME AND DECIMAL TIME SYSTEMS

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Technical Report

5. AUTHOR(S) *(Last name, first name, initial)*

Gray, T. Harrison, Waller, T. Gary, and Wright, Robert H.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
October 1966	31	3

8a. CONTRACT OR GRANT NO	9a. ORIGINATOR'S REPORT NUMBER(S)
DA 44-188-ARO-2	Technical Report 66-17
b. PROJECT NO. 2J024701A712 01	
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
Methods for Improving Navigation Training for Low-Level Flight	Office, Chief of Research and Development Department of the Army Washington, D.C. 20310

13. ABSTRACT

The study compared the efficiency of decimal and sexagesimal, or normal, time systems in the solution of addition problems, using the time required to reach a solution and the number of errors as dependent variables. Twelve subjects solved sets of addition problems composed of 8, 16, or 24 digits, using the decimal and sexagesimal time systems. When the conversion process required by the sexagesimal system was included in the analysis, the results clearly showed that addition using the sexagesimal system required significantly more time (1 1/2 to 2 1/2 times as much) and produced significantly more errors (1 1/2 to 3 times as many). When the conversion process required by the sexagesimal system was excluded from the analysis, there was no significant difference between the two time systems on either dependent variable.

DD FORM 1 JAN 64 1473

Unclassified

Security Classification

Unclassified
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Navigation Sexagesimal Time System Decimal Time System Addition Time Addition Accuracy						
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1 CLIN PSYCHOL SERV DEPT OF NEUROPSYCHIAT WALTER REED GEN HOSP
2 ENGNG PSYCHOL LAB PIONEERING RES DIV ARMY NATICK LABS NATICK MASS
1 TECH LIB ARMY NATICK LABS NATICK MASS
1 CG US ARMY MSL COMD REDSTONE ARSNL
1 CO ARMY PICTORIAL CTR LONG ISL ATTN APPLICAT DEVEL AB TV DIV
1 CG ARMY ELEC RG FT HUACHUCA ATTN TECH LIB
17 CO 1ST AIR DEF GUIDED MSL BNGD TNG FT BLISS
1 CG ARMY CBT DEVEL COMD FORCE CTR FT ORD
1 SIXTH ARMY LIB DEPOT PRES OF SAN FRAN
5 CG FT ORD ATTN G3 TNG DIV
1 DIR WALTER REED ARMY INST OF RES WALTER REED ARMY MED CTR
1 DIR WALTER REED ARMY INST OF RES WALTER REED ARMY MED CTR
ATTN NEUROPSYCHIAT DIV
1 CO HQ ARMY ENLISTED EVAL CTR + T SENJ HARRISON
1 DPTY FOR BIOASTRONAUT PG AIR PG CTR EGLIN AFB
1 CO FRANKFORD ARSNL ATTN SMUFA 1551/65-1
2 WALTER REED ARMY INST OF RES ATTN DEPT OF PSYCHIAT NEUROPSYCHIAT DIV
1 CG 5TH RGN HEADQUARTERS FT SHERIDAN ATTN G3 TNG
1 4TH RGN USARCENTM FT BAKER
1 11TH AIR ASSAULT DIV FT BENNING
1 PERS SURVS DIV CREW SURVS ONLY AEROMAT LAB DIV WRIGHT-PATTERSON AFB
1 USA ARMY BD FOR AVN ACCIDENT RES FT RUCKER
1 FIRST ARMY MSL COMD MED AGO 223 NY
2 CO PILATUNY ARSNL DOVER N J ATTN SMMPA VCI
1 INF SUPPLY AGY CAMERON STATION ATTN LIB
1 CO ARMY CBT DEVEL COMD FT BENJ HARRISON ATTN AVN CBN AGY
1 CBT OPNS RES GP ARMY CBT DEVEL COMD FT RELVOIR
ATTN OPNS ANLS HUMAN FACTORS
1 CO ARMY CBT DEVEL COMD AT BENNING ATTN INF AGY
1 CO ARMY CBT DEVEL COMD FT KNOX ATTN ARMOR AGY
8 ARMY CBT DEVEL COMD FT ORDAU ATTN SPEC WARFARE AGY
1 EVAL DIV OAO ARMY SIG CTR + SCH FT MONMOUTH
1 CHF CURRICULUM AB RESIDENT INSTR DEPT ARMY LOGISTICS MANGT CTR FT LEE
1 CO ARMY CBT DEVEL COMD SPEC TRAINING & EQUIPMENT GP FT BELVOIR
2 CDVEN PERS INFO US ARMY CBT DEV SYS FT LOUIS ATTN EMPLOYEE LEVEL OFCR
1 ARMY WAR COLL CARLISLE BKS ATTN LIB
1 ASST COMDT ARMY INTEL SCH FT HUACHUCA ATTN PLANS DIV OAO
1 COMDT COMD + GEN STAFF CO FT LEAVENWORTH ATTN ARCHIVES
7 DIR OF MILIT PSYCHOL + LDRSHP US MILIT ACAD WEST POINT
US MILIT ACAD WEST POINT ATTN LIB
1 COMDT ARMY AVN SCH FT RUCKER ATTN SCH LIB
1 COMDT ARMY SPECIAL AGY TNG CTR + SCH FT DEVENS ATTN LIB
1 COMDT ARMED FORCES INSTR COLL FT LESLEY J MCNAIR
2 COMDT NATL WAR COLL FT DRSLEY J MCNAIR ATTN CLASSF RECORDS AB LTR
1 WEP PLN SPEC SCH HEADQUARTERS USA ARMY MED CTR FT SAM HOUSTON ATTN STIMSON LIB
5 SUP OF INSTR ARMOR SCH FT KNOX
1 COMDT ARMY ORDNANCE SCH FT KNOX ATTN WEAPONS DEPT
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1 ARMY QM SCH FT LEE ATTN LIB
1 COMDT ARMY QM SCH FT LEE ATTN EDUC ADV
1 COMDT ARMY TRANS SCH FT EUSTIS ATTN EDUC ADV
1 COMDT ARMY MILIT POLICE SCH FT GORDON ATTN DIR OF INSTR
1 CG ARMY ORD CTR + SCH ABERDEEN PG ATTN ATSOM-CL
1 ASST COMDT ARMY AIR DEF SCH FT BLISS ATTN CLASSF TECH LIB
25 CG ARMY ARTY + MSL CTR FT SILL ATTN AVN OPER
1 COMDT ARMY DEF INTEL SCH ATTN STAFS DEPT
1 COMDT ARMED FORCES STAFF COLL NORFOLK
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2 COMDT ARMY PRIM HEL SCH FT WOLTERS
DIR OF MILIT INSTR US MILIT ACAD WEST POINT
1 SPEC WARFARE SCH FT BRGG ATTN LIB
1 ARMY SIG CTR + SCH AT MONMOUTH ATTN TNG LIT DIV OAO
2 SCH ARMY ORDNANCE GUIDED MISSILE SCH REDSTONE ARSNL
1 COMDT ARMY CHEMN CORPS SCH + CTR AT MCCLELLAN
2 HQ ABERDEEN PG ATTN TECH LIB
1 COMDT SAFE GM SCH FOR CTR OF NONRESID ACTVY FT LEE ATTN TNG MEDIA DIV
2 DIR RESD + DN OPNS DEPT USAIS FT BENNING
1 MED FLD SERV SCH BROOKE ARMY MED CTRFT SAM HOUSTON DEPT OF NEUROPSYCHIAT
2 DIR COMPANY TACTICS DEPT USAIS FT BENNING
1 SECY OF ARMY
1 DCS-PERS DA ATTN CHF CAS DIV
2 DACS FOR INTEL DA ATTN CHF CBT INTEL DEVEL DIV
1 CO FOREIGN SCI + TECH CTR MUN SEDG
2 AGS FOR FORCE DEVEL DA ATTN CHF TNG DIV
1 CHF OF ENGNRS DA ATTN ENGTE-T
1 HQ ARMY MAT COMD R+D DIRCTR ATTN AMCRD-BC
2 CG ARMY MED R+D COMD ATTN BEHAV SCI RES BR
1 ARMY PERS RES OFC ATTN CRD-AR
1 OFC OF PERS OPNS DA ATTN DPOSS-A
1 STANDARDS + SYS OFC DPO OCCUP R+D SECT ATTN DPOSS-A
1 ARMY PROVOST MARSHAL GEN
1 DIR CIVIL AFFAIRS DRCCIF ODCS-OPNS DA
1 OFC RESERVE COMPON DA
2 CHF ARMY SPT AGY ARLINGTON HALL STA ATTN ACS-G1

1 CG ARMY ELECT COMD FT MONMOUTH ATTN AMSEL CB
1 CHF OF R+D DA ATTN CHF TECH + INDSTR LIAISON OFC
1 EDUC + TNG BR CBT DEVEL + OPNS DIV OFC OF CHF SIG OFFR DA
1 PERS + TNG DIV DRDMC OFC OF CHF OF ORD DA
2 CG ARMY MED R+D COMD ATTN MEDDH-SR
1 ARMY PERS RES OFC ATTN CRD-AIC
1 COMDT ARMY CBT SURVEIL SCH FT HUACHUCA ATTN ATSUR S3
1 CG ARMY AIR DEF COMD ENT AFB
2 TNG + DEVEL DIV ODCS-PERS
1 PRES ARMY ARMOR BD FT ANUX
1 PRES ARMY MAINT BD FT KNOX
2 PRES ARMY AVN TEST BD FT RUCKER
2 PRES ARMY ARTY BD FT SILL
1 OPTY PRES ARMY MAT COMD BD ABERDEEN PG
1 PRES ARMY TRANS BD FT EUSTIS
1 CO ARMY CBT DEVEL COMD MILIT POLICE AGY FT GORDON
1 CG 2D ARMORED DIV FT HOOD ATTN DIV AVN OFCR
6 CG 4TH ARMORED DIV APO 32A NY
1 CO 6TH ARMOR GP APO 757 NY
2 CO 14TH ARMOR GP FT IRWIN
6 CO 2D ARMORED CAV REGT APO 696 NY
1 CO 3D ARMORED CAV REGT APO 34 NY
1 CO 14TH ARMORED CAV REGT APO 28 NY
2 CG ARMY ARMOR + ARTY FIRING CTR FT STEWART ATTN ACS-G3 TNG OFCR
1 1ST ARMORED DIV HQ+HQ CO FT HOOD ATTN ACS-G2
1 1ST CAV DIV 3D MED TANK BN 69TH ARMOR APO 24 SAN FRAN
10 1ST INF DIV 1ST MED TANK BN 63D ARMOR FT RILEY
6 3D INF DIV 1ST BN 64TH ARMOR APO 36 NY
1 1ST TANK BN 73D ARMOR 7TH INF DIV APO 7 SAN FRAN
4 4TH INF DIV 2D BN 68TH ARMOR APO 14 NY
1 CO COMPANY A 3D BN 32D ARMOR 3D ARMORED DIV (SPEARHEAD) APO 39 NY
1 CO 5TH BN 33D ARMOR FT KNOX
1 6TH 3D MED TANK BN 68TH ARMOR APO 28 NY ATTN S3
1 CO 3D MED TANK BN 17TH ARMOR APO 36 NY
1 CO 4TH MED TANK BN 68TH ARMOR APO 28 NY
3 CO 2D BN 34TH ARMOR FT IRWIN
2 CALIF NG 40TH ARMORED DIV LOS ANGELES ATTN ACS-G3
1 59TH COMD HQ DIV ARMY NG JACKSONVILLE FLA
4 CO 150TH AVN BN NJ AIR NG ELIZABETH
1 CG HQ 27TH ARMORED DIV NY AIR NG SYRACUSE
1 TEXAS NG 49TH ARMORED DIV DALLAS
2 CO 3D [illegible] BN 32D ARMOR APO 29 NY
1 CG ARMY ARMOR CTR FT KNOX ATTN G3 ATBKGT
2 CG 1ST INF DIV FT RILEY ATTN G3
1 CG 2D INF DIV FT BENNING ATTN DIV AVN COMOR
4 CG 4TH INF DIV FT LEWIS ATTN G3
1 CG 8TH INF DIV APO 111 NY ATTN G2
1 CG 5TH INF DIV (MECH) FT CARSON
5 CG 24TH INF DIV APO 112 NY ATTN G3
1 CG HQ US ARMY HAWAII APO 957 SAN FRAN ATTN G2
3 CO 82D ABN INF DIV FT BRAGG ATTN G3
1 CO 1ST BN (AIRINF) 3D INF (THE OLD GUARD) FT MYER
1 CO HQ 2D BN 4TH INF REGT APO 742 NY
1 CO 3D BN 6TH INF REGT APO 742 NY
1 CO 1ST INF BRGD APO 731 SEATTLE
3 CG 25TH INF DIV APO 25 SAN FRAN
1 CO 2D BG 51ST INF REGT FT RUCKER
1 CO 3D BN 19TH INF APO 24 NY
1 CO 1ST BN 39TH INF APO 28 NY
6 CO 1ST BN (MECH) 52D INF 1ST ARMORED DIV (OLD IRONSIDES) FT HOOD
6 4TH BN (MECH) 50TH INF FT KNOX
1 CO ARMY PARTIC GP NAV TNG DEVICE CTR PT WASHINGTON ATTN CODE 01A
2 CO HQ ARMY AVIATION GROUP (ATNG) + VISUAL ACTVY PACIFIC APO 331 SAN FRAN
ATTN PUBS PROC OFC
2 CHF AUDIO VISUAL APPLICAT OFC ARMY PICTORIAL DIV OFC OF CHF SIG OFCR
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1 CG MILIT DIST OF WASHINGTON
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2 HQ 67/59TH ARTY HAMPTON ROS ARMY TERM NORFOLK
1 28TH ARTY GP AIR DEF SELFRIDGE AFB
1 52D ARTY BRGD AIR DEF HIGHLANDS AFS
1 HQ 45TH ARTY BRGD AIR DEF ARLINGTON HTS ILL
1 38TH ARTY BRGD AIR DEF FT GEO G MEADE
1 CO ARMY AVN TEST BD FT RUCKER
1 CG 101ST ABN DIV FT CAMPBELL
1 CG 1ST CAV DIV APO 24 SAN FRAN
1 ARMY QM R+D FEA FT LEE ATTN TECH LIB
1 CHF BEHAV SCI RES BR ARMY MED R+D COMD
2 PRES ARMY FINANCE CORPS BR
1 ARMY R+D OFC PANAMA FT CLAYTON CANAL ZONE ATTN BEHAV SCI COORD
2 CINC US PACIFIC FLT FPO SAN FRAN
1 CINC PACIFIC OPNS ANLS SECT FPO SAN FRAN
1 CHF BUR OF MED + SURG DN ATTN CODE 513
1 MEAD CLIN PSYCHOL SECT PROFESNL DIV BUR OF MED + SURG DN
5 BUR OF NAV PERS ATTN TECH LIB PERS 11B
1 DIR PERS RES DIV BUR OF NAV PERS
1 PERS + TNG BR PSYCHOL SCI DIV OFC OF NAV RES
1 CO + DIR NAV TNG DEVICE CTR PT WASHINGTON ATTN LIBN
2 NAV MSL CTR POINT MUGU CALIF ATTN HUMAN FACTORS ENGNR DIV
1 CO NAV AIR DEVEL CTR JOHNSVILLE PENNA ATTN NADC LIB
2 PLT ANTI-AIR WARFARE TNG CTR DAM NECK VA BEACH
2 CO FLT TNG CTR NAV BASE NEWPORT
2 OIC ATLANTIC FLT MSL WEAPON SYS TNG UNIT FLT ANTI-AIR WARFARE TNG CTR
DAM NECK VA BEACH
2 CO FLT TNG CTR NORFOLK
2 HUMAN FACTORS DEPT COMM PSYCHOL DIV NAV TNG DEVICE CTR PT WASHINGTON
1 CLIN PSYCHOL MENTAL HYGIENE UNIT US NAV ACAD ANNAPOLIS
1 PRES NAV WAR COLL NEWPORT ATTN MAHAN LIB
2 CO + DIR ATLANTIC FLT ANTI-SUB WARFARE TACTICAL SCH NORFOLK
1 CO NUCLEAR WEAPONS TNG CTR ATLANTIC NAV AIR STA NORFOLK
2 CO FLT ANTI-AIR WARFARE TNG CTR DAM NECK VA BEACH
2 CO FLT SONAR SCH KEY WEST
1 CHF OF NAV RES ATTN HEAD PERS + TNG BR CODE 458

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1 CHP OF NAV RES ATTN DIR PSYCHOL SCI DIV CODE 450
1 CHP OF NAV RES ATTN HEAD GP PSYCHOL BR CODE 452
9 CO OPC OF NAV RES BR OPC FPO 39 NY
1 CHP OF NAV AIR TNG TNG RES DEPT NAV AIR STA PENSACOLA
1 CO NAV SCH OF AVN MED NAV AVN MED CTR PENSACOLA
1 CO MED PLD RES LAB CAMP LEJEUNE
1 CDR NAV MSL CTR POINT MUGU CALIF ATTN TECH LIB CODE 3022
2 OIC NAV PERS RES ACTVY SAN DIEGO
1 NAV AIR TECH TNG CTR MEMPHIS
1 PAV NEUROPSYCHIAT RES UNIT SAN DIEGO
2 CDR NAV MSL CTR POINT MUGU CALIF ATTN HUMAN ENGNR DIV CODE N-335
1 OIC NAV PERS RES ACTVY NAV STA NAV [illegible] WASHINGTON
1 NAV TNG PERS CTR NAV STA NAV YD ANNEX WASHINGTON ATTN CODE 83 LIB
1 COMDT MARINE CORPS HQ MARINE CORPS ATTN CODE AO-1B
1 HQ MARINE CORPS ATTN AX
1 DIR MARINE CORPS POUC CTR MARINE CORPS SCH QUANTICO
ATTN SECRET + CONF FILES GP
1 DIR MARINE CORPS INST ATTN EVAL UNIT
1 CHP OF NAV OPNS OP-91P1
1 CHP OF NAV OPNS OP 031
1 CHP OF NAV OPNS OP-0772
1 CHP OF NAV AIR TECH TNG NAV AIR STA MEMPHIS
2 COMDT PTP COAST GUARD HQ
1 CHP OPCR PERS RES + REVIEW BR COAST GUARD HQ
1 OPNS ANLS OPC HQ STRATEGIC AIR COMD OFFUTT AFB
1 AIR TNG COMD RANDOLPH AFB ATTN ATFTN
1 HQ AIR FORCE ATTN AFCIN-3D1
1 CHP SCI DIV ORCTE SCI + TECH OCS R+D HQ AIR FORCE AFRSTA
1 CHP SPEC WARFARE DIV ORCTE OF PLANS + OPNS OCS-PLANS+OPNS
HQ AIR FORCE
1 CHP OF PERS RES BR ORCTE OF CIVILIAN PERS OCS-PERS HQ AIR FORCE
1 CHP EVAL BR (APPROP) CAREER DEVEL DIV ORCTE OF PERS PLAN HQ AIR FORCE
1 AIR FORCE STAFF COLL SCI + TECH LIAISON OFC (RTSNWT CO ON
1 CHP COMM STUDY GP SAMTAG BOLLING AFB STOP 8-29
1 PEO AVN AGY MED LIA HQ-AAO
1 HQ AIR FORCE STAFF COLL SCGB 5 ANDREWS AFB
1 ROME AIR DEVEL CTR RASH GRIFFISS AFB
2 CDR ELEC SYS DIV L G HANSCOM FLD BEDFORD MASS ATTN ESMD
2 SACRAMENTO AIR MAT AREA SMACU-PERS RES MCCLELLAN AFB
1 AIR TNG COMD ATTNS W RANDOLPH AFB
1 AFRO MED RES LAB WRPTO WRIGHT-PATTERSON AFB
1 HQ BALLISTICS SYS DIV PERS SUBSYS BR BSDSP NORTON AFB
2 WILIT TNG CTR OPE LACKLAND AFB
2 AFTOTH AERO MED RES LAB WRPT WRIGHT-PATTERSON AFB
1 AIR HOVEMENT DESIGNATOR ARMH BRDORS AFB
1 OCS-TECH TNG DIR WILIT + SPT TNG RANDOLPH AFB
4 HQ AIR TRANS COMD ATCTO-M RANDOLPH AFB
1 CDR ELEC SYS DIV LG HANSCOM FLD ATTN ESTI
1 DIR AIR U LIB MAXWELL AFB ATTN AUL-8-AA-253
1 AIR FORCE SCH OF AEROSPACE MED BROOKS AFB ATTN AEHINFO LIB
1 DIR OF LIB US AIR FORCE ACAD
1 COMDR ARCTIC AEROMED LAB APO 731 SEATTLE
1 AFTAT: [illegible] RES LAB PRA-4 AEROSPACE MED DIV LACKLAND AFB
1 TECH TNG CTR INT LOWRY AFB
1 DIR NATL SECUR AGY FT GEO G MEADE ATTN DIR OF TNG
9 CENTRAL INTEL AGY ATTN OCR MAIL CH
1 DEPT OF STATE BUR OF INTEL + RES EXTERNAL RES STAFF
1 SCI INFO BRCH WASHINGTON
2 CHP REGL TNG BR TNG DIV PEO AVN AGY ATTN PT 3R
1 CHP PERS RES STAFF OPC OF PERS DEPT OF AGRICUL
1 RES INFO CTR NATL BUR OF STANDARDS ATTN RES PSYCHOL
1 CHP PSYCHOL BR CIVIL AEROMED RES INST FED AVN AGY OKLAHOMA CITY
1 SYS DEVEL CORP SANTA MONICA ATTN LIB
2 DUNLAP + ASSOC INC DARIEN ATTN LIB
2 RES ANLS CORP MCLEAN
1 RAND CORP WASHINGTON ATTN LIB
1 U OF ILL GP EFFECTIVE RES LAB
2 U OF SO CALIF ELEC PERS RES GP
1 COLUMBIA U ELEC RES LABS ATTN TECH EDITOR
1 MITRE CORP BEDFORD MASS ATTN LIB
1 WESTERN ELECTRIC CO WINSTON-SALEM
2 U OF PGH LEARNING RES CTR ATTN DIR
1 HUMAN SCI RES INC NORFOLK
1 WESTERN ELECTRIC CO INC NY
1 HUMAN SCI RES INC MCLEAN VA
2 TECH INFO CTR ENGNR DATA SERV N AMER AVN INC COLUMBUS O
1 CHRYSLER CORP MSL DIV DETROIT / ATTN TECH INFO CTR
1 CTR FOR RES IN SOCIAL SYS AMER U ATTN LIBN
1 RAYTHEON CO ELEC SERV OPNS BURLINGTON MASS
2 EDUC + TNG CONSULTANTS LOS ANGELES ATTN PRINCIPAL SCI
1 GEN DYNAMICS POMONA CALIF ATTN LIB
1 AVN CRASH INJURY RES SAN HARBOR AIRPORT PHOENIX ATTN TECH LIBN
2 MARQUARDT CORP POMONA CALIF ATTN DEPT 460
1 REFLECTONE ELEC INC STAMFORD CONN
1 CHP PERS SUBSYS AIRPLANE DIV MS 74-90 RENTON WASH
1 SYLVANIA ELECTRIC PRODUCTS INC NEEDHAM HGTS MASS ATTN PERS SUBSYS MANGR
1 THIOKOL CHEM CORP HUNTSVILLE DIV LOS ANGELES ATTN LIBN
2 CTR FOR RES IN SOCIAL SYS FLD OFC OFSECT SPEC WARFARE SCH FT BRAGG
1 DIR OF RELIABILITY + VALUE ENGNR BELL AEROSYS CO BUFFALO
1 INST RES OPR ANLS RES + ENGNR SUPPORT DIV WASHINGTON
1 HUGHES AIRCRAFT COMPANY CULVER CITY CALIF
1 DIR CTR FOR RES ON LEARNING + TEACHING U OF MICH
1 OHIO STATE U
1 BOSTON TNG RES ABSTR AMER SOC OF TNG DIRS U OF TENN
1 U OF CHICAGO DEPT OF SOC
1 GEO WASHINGTON U DEPT OF PSYCHOL
1 HUMAN FACTORS SPCT R+D GEN DYNAMICS ELECTRIC BOAT GROTON
1 CTR FOR RES IN SOCIAL SYS AMER U
6 BRITISH EMBSY BRITISH DEP RES STAFF WASHINGTON
9 CANADIAN JOINT STAFF OPC OF DEP RES MEMBER WASHINGTON
9 CANADIAN ARMY STAFF WASHINGTON ATTN GSO2 TNG
2 CANADIAN LIAISON OPCR ARMY ARMOR BD FT KNOX
9 ACS FOR INTEL FOREIGN LIAISON OPCR TO NORWEG MILIT ATTACHE
1 ACS FOR INTEL FOREIGN LIAISON OPCR FOR SWEDISH EMBSY ATTN ARMY ATTACHE
1 NATL INST FOR ALCOHOL RES OSLO
2 FRENCH LIAISON OFCR ARMY AVN TEST BD FT RUCKER
1 BRITISH LIAISON OFCR ARMY AVN TEST BD FT RUCKER
1 AUSTRALIAN EMBSY OPC OF AIR ATTACHE WASHINGTON ATTN T A NAVGN SQDN LDR
1 YORK U DEPT OF PSYCHOL
2 AUSTRALIAN EMBSY OPC OF MILIT ATTACHE WASHINGTON
2 U OF SHEFFIELD DEPT OF PSYCHOL
1 MENNINGER FOUNDATION TOPEKA
2 AMER INST FOR RES WASHINGTON
1 AMER INST FOR RES PGH ATTN LIBN
1 COLUMBIA U SCH OF BUS
9 MATRIX CORP ARLINGTON ATTN TECH LIBN
1 AMER TEL+TEL CO NY
1 U OF GEORGIA DEPT OF PSYCHOL
1 ONR-LIN COLL DEPT OF PSYCHOL
1 GEN ELECTRIC CO SANTA BARBARA ATTN LIB
1 VITRO LABS SILVER SPRING MD ATTN LIBN
1 TENN VALLEY AUTHORITY KNOXVILLE ATTN LABOR RELATIONS OFCR DIV OF PERS
1 U OF GEORGIA DEPT OF PSYCHOL
1 U OF UTAH DEPT OF PSYCHOL
1 AMER INST FOR RES LOS ANGELES
1 AMER INST FOR RES PALO ALTO CALIF
1 MICH STATE U COLL OF SOC SCI
1 N MEX STATE U
1 ROWLAND + CO HADDONFIELD NJ ATTN PRES
1 NORTRONICS DIV OF NORTHROP CORP ANAHEIM CALIF
1 AIRCRAFT ARMAMENTS INC COCKEYSVILLE MD
2 OREGON STATE U DEPT OF MILIT SCI ATTN ADJ
1 TUFTS U HUMAN ENGNR INFO + ANLS PROJ
1 AMER PSYCHOL ASSOC WASHINGTON ATTN PSYCHOL ABSTR
1 [illegible] ILL U HEAD DEPT OF PSYCHOL
1 GEORGIA INST OF TECH DIR SCH OF PSYCHOL
1 OHIO STATE U DEPT OF AVN
1 REPUBLIC AVN CORP FARMINGDALE LONG ISL ATTN SUPERV ENGNR LIB
1 WASHINGTON ENGNR SERV CO INC KENSINGTON MD
1 LTPF SCI INC FT WORTH ATTN PRES
1 AMER REHAV SCI NY
1 INTERNATL INVENTORS CONGRESS CHICAGO
2 DIR INSTR RESOURCES STATE COLL ST CLOUD MINN
1 COLL OF WM + MARY SCH OF EDUC
1 SO ILLINOIS U DEPT OF PSYCHOL
2 COMMUNICABLE DISEASE CTR DEVEL + CONSULTATION SERV SPCT ATLANTA
1 NORTHWESTERN U DEPT OF INDSTR ENGNR
1 NY STATE EDUC DEPT ABSTRACT EDITOR AVCR
1 CHP PROCESSING DIV DUKE U LIB
1 U OF CALIF GEN LIB DOCU DEPT
1 FLORIDA STATE U LIB GIFTS + EXCH
1 HARVARD U PSYCHOL [illegible] LIB
1 U OF ILL LIB SER DEPT
2 U OF KANSAS LIB PERIODICAL DEPT
1 U OF NEBRASKA LIBS ACQ DEPT
1 OHIO STATE U LIBS GIFT + EXCH DIV
1 PENNA STATE U PATTEE LIB DOCU DESK
1 PURDUE U LIBS PERIODICALS CHECKING FILES
1 STANFORD U LIBS DOCU LIB
1 LIBN U OF TEXAS
1 SYRACUSE U LIB SER DIV
1 U OF MINNESOTA LIB
1 STATE U OF IOWA LIBS SER ACQ
1 NO CAROLINA STATE COLL DH HILL LIB
2 BOSTON U LIBS ACQ DIV
1 U OF MICH LIBS SER DIV
1 BROWN U LIB
2 COLUMBIA U LIBS DOCU ACQ
1 DEP JOINT U LIBS NASHVILLE
1 U OF OKLA [illegible] REED LIB
2 GEN U LIB GEO WASHINGTON U
2 LIB OF CONGRESS CHP OF EXCH + GIFT DIV
1 U OF PGH DOCU LIBN
1 OPC OF DIR CATHOLIC U LIB ATTN PSYCHOL DEPT LIB
1 U OF KY MARGARET I KING LIB
1 SO ILL U ATTN LIBRN SER DEPT
1 KANSAS STATE U FARRELL LIB
1 BRIGHAM YOUNG U LIB SER SECT
1 AVIONICS + NAVGTN AIDS COMMODITY OPC USA ELEC COMD FT MONMOUTH ATTN CHP
1 USA CDEC FT ORD ATTN [illegible] OPCR
1 DISPLAY SYS DEPT HUGHES AIRCRAFT CO CULVER CITY CALIF
1 CO WRIGHT PATTERSON AFB ATTN SRC SEMP
1 R A MONTY CORNELL AERONAUTICAL LAB INC BUFFALO NY
1 PGTA OPTY FOR EFFECTIVENESS TEST PGT EGLIN AFB
1 LCDR BARRINEAU US NAV ORD LAB WHITE OAK SILVER SPRING MD
1 DR ELRIN IBM SPACE GUIDN CTR OSWEGO NY
1 AUTONETICS ANAHEIM CALIF ATTN TECH LIB DEPT 502 13 120 BLDG 290
1 DR D TALCOTT WRIGHT PATTERSON AFB ATTN SEMCP
1 T A MCCARTY APPLIED PHYSICS LAB JOHN HOPKINS UNIV SILVER SPRING MD
1 DIR AIRBORNE AIR MOBILITY DEPT USAIS FT BENNING
1 T G WALLER PSYCHOL DEPT VANDERBILT UNIV NASHVILLE TENN
1 R G STINNAMON AVN MED ACCELERATION LAB USN AIR DEVEL CTR JOHNSONVILLE PA
1 HUGHES AIRCRAFT CO CULVER CITY CALIF ATTN A C ROSENBERG TECH DOCU CTR
1 DR J WHITTENBURG HUM SCI RES INC MCCLEAN VA
1 BEN SCHEMMER MILIT AIRCRAFT SYS DIV BOEING CO SEATTLE WASH
1 DIR AVN SAFETY DIV UNIV OF SO CALIF LOS ANGELES
3 CO 24TH DIV MECH ARTY AVN SECT APO 29 NEW YORK
1 OPC OF SURG GEN DA ATTN AVN SECT
1 USA TRANS RES COMD FT EUSTIS ATTN F MCCOURT